TRANSACTIONS
OF THE
ILLUMINATING ENGINEERING SOCIETY

FOUNDED
IN LONDON
1909

INCORPORATED
1930

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VOLUME XIV
No. 10 — 1949

32 VICTORIA ST
LONDON, SW1

Annual Subscription to Non-Members - £2.2.0
Price per Number to Non-Members - 5s. 0d.

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Specialised and General Lighting in Hospitals

M. W. PEIRCE *(Fellow)* and D. J. REED *(Member)*.

Summary

This paper discusses some of the lighting requirements in hospitals, and describes ways in which they are satisfied. The lighting of the operating theatre is considered in some detail and an attempt has been made to classify systems of lighting according to their suitability for different surgical operations.

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(1) Introduction

Each piece of equipment in a hospital should contribute something either directly or indirectly towards the treatment of the patient, and without doubt the lighting installation is an important part of the equipment. An incorrectly designed lighting system may easily retard the recovery of a patient, so before putting forward an illumination scheme it is important to understand the true purpose for which the artificial lighting is required.

The material in this paper is presented in the form of solutions to the lighting problems which confront the Illuminating Engineer in the various parts of hospital buildings. An attempt has been made to analyse the visual task in each case and suggestions for lighting are based upon these analyses.

(2) Ward and Corridor Lighting

(2.1) Requirements

In a hospital ward the lighting needs of the patients and of the nursing staff must be considered. Depending upon his condition, the patient may require comparative darkness or he may need sufficient light to carry out various kinds of occupational therapy. It is important, therefore, to ensure that any lighting being used by one patient does not cause discomfort to another who is resting.

General lighting is needed to engender a cheerful atmosphere in the ward but must be of such a nature that it does not disturb any occupant of the room. Good lighting must be available for the nursing staff to carry out their duties of examining

The authors are with the General Electric Company, London. Manuscript received on June 21, 1949, and in revised form, September 7, 1949. Presented at the meeting of the Society held in London, November 8, 1949.

patients at any time throughout the night or day. Requirements for lighting through the night may vary in different wards, but all require a general glimmer to enable the Night-nurse to make her rounds. Some wards require a strictly limited area having more light, where medicines may be prepared without error, and where reports may be written.

It is important to keep the illumination in the corridors at about the same level as that in the wards, so that when the staff have to move about the building, their adaptation level may be maintained constant.

The corridor lighting must provide for the safe movement of patients and equipment at all times. The patient is normally moved on a stretcher-trolley and his point of view as he passes beneath the sources of light must be considered. While it is desirable to provide for reduced lighting during the night it is, nevertheless, essential to ensure that such reduced lighting does not leave unlighted areas with the consequent danger of accidents to members of the night staff. A system whereby some of the corridor lights are switched off after a certain hour, is likely to be unsatisfactory from this point of view.

Where there are glass partitions between wards and corridors, the possibility of the corridor lights annoying the patients during the night must be considered.

(2.2) Recommendations

It does not seem possible to meet the foregoing requirements unless general lighting together with local lighting in various forms is used because, on the one hand, the use of local lighting alone will not give the cheerful atmosphere which is necessary in the ward and, on the other, the needs of the patient cannot be satisfied by unaugmented general lighting.

If the principle is accepted that local lighting for the patients will be provided, then the light distribution from the general lighting fittings can be strictly controlled. The fitting must have a low brightness when seen by any patient, but need not be controlled in other directions. A suitable distribution can be obtained by a louvre system (this is particularly applicable to linear sources), or diffusing globes for filament lamps may be used. Such globes should be larger than usual for the size of lamp employed and a brightness of 1 candle per sq. inch. should not be exceeded. Table 1

Table 1.

Diffusing Globe Sizes

Lamp Wattage	Usual globe diameter (ins.)	Theoretical diam. for 1 C/sq. in.	Recommended Standard Globe diameter (ins.)
60	8	7.75	8
75	8	8.75	10
100	10	10.50	12
150	12	13.00	14
200	14	15.3	16

shows lamp sizes and the theoretical size of globe to give 1 cd. per sq. in. In calculating these sizes, it has been assumed that the glassware has an efficiency of 80 per cent., and that the canopy covers about 6 per cent. of the surface of the globe. Also shown in the table is the size of globe usually associated with a particular lamp, and the size recommended so that the brightness does not exceed 1 cd. per sq. in.

Even at these low brightnesses it is important to ensure that the brightness contrast between the fitting and its background is kept to a minimum, by keeping the

ceilings and upper parts of the walls as light in colour as possible and allowing the maximum amount of light to reach these areas.

Fig. 1 shows a ward in the Royal Surrey County Hospital, Guildford, in which are six general lighting fittings. Each fitting accommodates one 5 ft. 80 watt fluorescent "Natural" lamp and is arranged for down-rod suspension. A transverse louvre system level with the bottom of the fitting gives a cut-off of 45 deg. in all directions below the horizontal, while an open top to the fitting allows light to reach the ceiling. The fittings were tried out at different mounting heights and the best effect was found to occur when the top of the fitting is 4 ft. from the ceiling. For night lighting, a 15 watt Pigmy blue-sprayed tungsten lamp is installed at each end of the fitting, and additional louvres maintain the 45 deg. cut-off for these lamps.

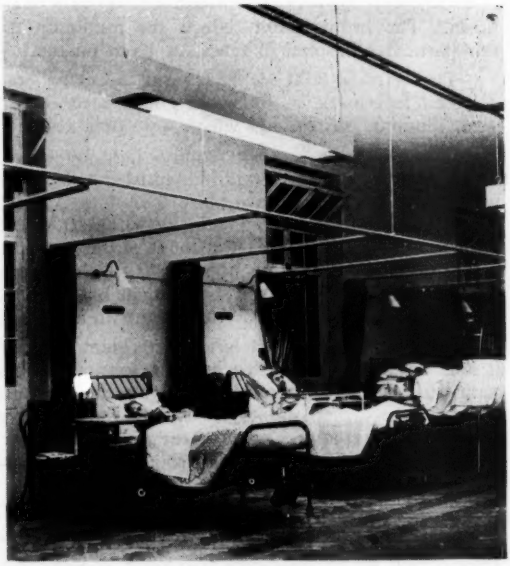

Fig. 1. Louvred fluorescent ward fittings at the Royal Surrey County Hospital.

The installation was erected in two parts, three fittings being supplied initially for experimental tests. Each of these three fittings had its louvres painted a different shade of grey, one dark, one medium and one light. Of these, the dark grey was chosen unanimously by patients and staff as being the most acceptable colour when used in conjunction with the Natural colour lamp, although the original glossy finish gave rise to troublesome reflections. When the blue tungsten lamps were switched on, the louvres illuminated by these lamps had too high a brightness for comfort. Subsequently, one of the fittings was painted internally with a matt dark brown paint, and the improvement was so marked that this colour has now been adopted as the standard

Table 2.

Illumination in Hospital Ward

Position	Illumination (lm./ft.²)	
	At floor level	At 3 ft. from floor
Under end of fitting	6.5	8.0
Under centre of fitting	7.0	10.0
Midway between fittings	6.0	7.0
At bed foot	3.0	1.5
At bed head	1.0	1.0

finish. The brown paint reflects the minimum light from the blue lamps, and in this particular hospital matches the paint on the lower part of the ward walls.

The ward is 70 ft. × 25 ft. with a ceiling height of 14 ft. The six fittings are disposed lengthwise in the ward and spaced equally along the centre-line. Table 2 gives illumination readings which were obtained in the ward at night.

If a bed-ridden patient requires light by which to read or perform other visual tasks, he may use his own individual bed-light. For this reason, general lighting will not be required to give more than 1 or 2 lm./ft.^{2} at the head of the bed. Elsewhere in the ward an illumination of 10 lm./ft.^{2} would not be excessive, for this would provide a well-lighted area for convalescing patients to sit, and read or write, or play games, as well as for the nursing staff to do those duties not done at the bedside. Thus, although an ordinary room might be lighted with two or three rows of fittings, it is preferable to light a hospital ward with a centre row only. (Fig. 2.)

In children's wards it is less important to provide local lights to each bed than it is in adult wards, for two main reasons. Firstly, many of the patients may be too young to read or write, and, secondly, because children of any age in a children's ward are less likely than adults to occupy their time in bed with activities calling for prolonged visual application. If the number of local lights is reduced, then the general lighting must be increased accordingly and arranged to illuminate the ward more uniformly.

The practice of keeping ophthalmological wards in a perpetual state of semi-darkness is passing and these wards are now treated normally. The daylighting of these wards, particularly, can be a cause of discomfort to patients if the usual arrangement of beds is adhered to and a patient is able to see the windows across the ward, for the contrast between the bright windows and the wall space between them may easily be unpleasantly high. One suggestion that has been put forward to the authors

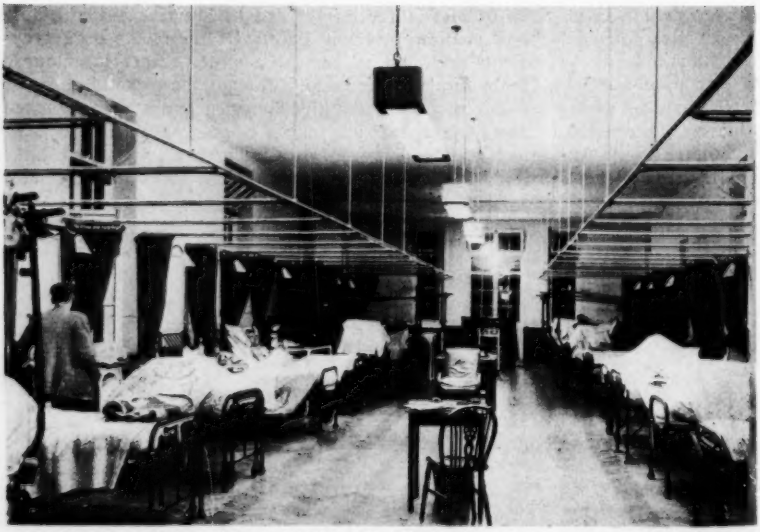

Fig. 2. General view of the ward shown in Fig. 1 showing central suspension of fittings.

to overcome this is to arrange the beds parallel to the walls containing the windows instead of at right-angles to them as is more usual.

For local lighting at the bed-head, a wall-mounted fitting should be used. The light should be under the control of the patient, and should be designed to light one bed only so that other patients are not affected by it. The fitting should be mounted at about 4 ft. 6 in.—5 ft. from the floor and equipped with a 40w. or 60w. tungsten filament lamp. Fittings at this mounting height are below the eye-level of persons walking in the ward, and may be easily reached for maintenance. To light one bed only without causing glare to any other patients, it is essential to use a cut-off type of fitting, and it will be found desirable to reduce the skirt-glare. One way in which this may be done is to paint the bottom inch of the inside of the skirt with matt black paint. To obviate the use of torches there should be available in each ward a portable standard lamp which can be used when a patient has to be treated in his bed.

The reduced general illumination at night can be provided by an indirect glow from low-wattage lamps, which are sometimes colour-sprayed, incorporated in the general lighting fittings used by day. An alternative system uses small fittings mounted on the walls below the level of the patient and arranged so that all the light is directed towards the floor. This gives an adequate light for the movement of the nursing staff without disturbing the patients who may be asleep.

A small area of high intensity required at night for the preparation of medicine and the writing of reports can be provided by a small concentrating reflector in the bottom of one of the general lighting fittings. Sometimes, however, there is a small annexe to the ward where the nurses can do their administrative work between their rounds at night. This permits a higher illumination than in the ward, but it is suggested that red coloured lamps be used in the annexe to preserve the nurses' dark adaptation.

The use of similar types of fittings in the corridors to those in the wards will maintain a uniform appearance throughout the hospital and also make it easier to

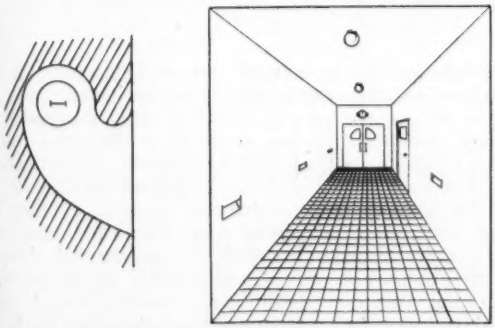

Fig. 3. Low mounted fittings for corridor lighting.

ensure that the illumination levels are similar. The dual-purpose pendant fitting with low-wattage night lighting; alternatively, recessed fittings in the walls would be satisfactory. (Fig. 3.) Whichever system is used, there will be no discomfort to patients in wards separated from the corridors by glass-topped partitions.

(3) Operating Theatres

(3.1) Requirements

The visual tasks performed in the theatre are far more exacting than those elsewhere in the hospital and it follows that the lighting must be of a much higher standard.

The basic lighting problem is the same as in all other situations, namely, to

enable the worker to see what he is doing, the term "worker" including the surgeon and his team of assistants. No member of this team should be hampered by glare or by lack of light wherever he may be in the theatre. While the surgeon will require a high level of shadowless illumination, there must also be a good general illumination to enable his assistants to fulfil their duties.

It will be necessary to consider the types of operation a surgeon will have to perform and for purposes of lighting it is possible to classify surgical work into four groups:—

Group 1.—Surface operations and operations where there is no particular cavity.

Group 2.—Operations on deep-seated organs that can be brought to the surface for examination.

Group 3.—Deep cavity operations where the size of the initial incision is comparatively large.

Group 4.—Deep cavity operations where the size of the initial incision is very small.

The ideal theatre fitting would be one which, while providing adequate illumination for all these groups, would also fulfil the following requirements:—

Comfort.—As the surgeon is working at a high pitch of mental and physical tension, his comfort is obviously of extreme importance.

Colour.—The colour rendering properties of the light source in the operating theatre fitting will be important since both the surgeon and the anaesthetist assess the patient's condition by his appearance.

Cleanliness.—Lighting fittings should be designed so that they can be kept clean easily.

Adaptability.—Fittings should be capable of easy adjustment so that the surgeon is able to control the lighting to meet his changing requirements during the course of an operation.

(3.2) Recommendations

(3.2.1) *Shadowlessness.*

Since the term "shadowless lighting" has been stated to be a requirement for the surgeon, it is desirable to understand exactly what is implied by this designation.

If an object is so lighted that no shadows are cast, it is difficult to distinguish its conformation and for this reason shadowless lighting would place the surgeon at a disadvantage. What is required is a lighting system in which the maximum illumination is obtained at the point where it is most needed, with the minimum interference by shadowing. It is quite beside the point to test the shadowlessness of a fitting by holding an extended hand a few inches above a sheet of paper below the fitting and observing the shadow, when in practice the point at which the surgeon is looking is not likely to be shadowed by his hand, which will almost certainly be to one side. It is possible, however, that the surgeon's head may obstruct useful light flux and the more logical method of testing the shadowlessness is to lean into the beam as though performing an operation and to observe the shadowing which then results. (Figs. 4 and 5.)

It is impossible to design a fitting embodying all the requirements asked for because in surface work a large source of low brightness will be satisfactory, for it will give the shadowless quality which is desired, but for cavity work a greater degree of penetration of light is needed which will inevitably reduce the shadowlessness. In calculating the amount of light at the bottom of a cavity, it is necessary to consider the area of the source visible at the bottom and the source brightness. The product of these two quantities will be a maximum if a small source of high brightness

Fig. 4. Usual but incorrect method of testing for shadow effect.

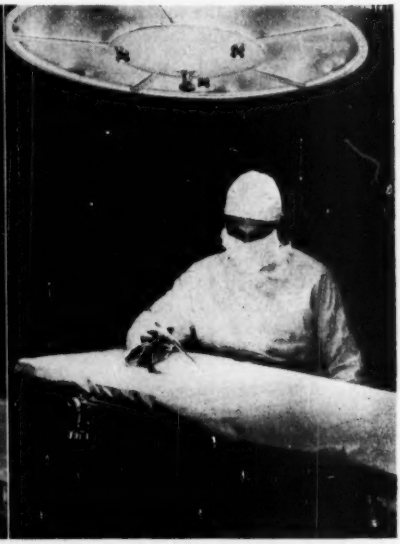

Fig. 5. More logical method of testing for shadow effect.

is used in conjunction with a concentrating reflector. Such a unit will not have the shadowless qualities already mentioned and the head of the surgeon is very likely to obstruct a large part of the light source. If the shadowless quality is improved by increasing the effective size of the light source, and decreasing the amount of light projected from the centre of the fitting, then it is clear that the cavity illumination will be reduced. The conclusion is, therefore, that a compromise must be made between the two extremes: the small source giving maximum illumination and a possibility of shadowing, and the large source giving poorer cavity illumination but less shadowing. In practice a large source is used for the majority of surgical work and a small spot light should be available for deep cavity operations.

(3.2.2) *Intensity*.

For much of the surgeon's work illumination levels of 50-60 lm./ft.^{2} might be adequate, but because so much light is lost in penetrating deep cavities, higher levels

Table 3.

Illumination Provided by Various Types of Operating Theatre Fitting

Type of Operating Theatre Fitting	Illumination at working area (lm./ft.2)
Large circular fitting with Tungsten lamp ...	up to 700
Multi-source ceiling	150
Elliptical dome	200
Fluorescent reflector fitting	400

become necessary so that there will still be enough light for acute vision, after provision has been made for the losses. The illumination given by various types of equipment available for operating table lighting varies between 150 and 700 lm./ft.^{2} as shown in Table 3.

Where a single 150- or 200-watt tungsten lamp is used, the resulting spot is relatively small. On the other hand, if fluorescent lamps are used, a large area must of necessity be illuminated because the light from the large source cannot be concentrated into a small area.

(3.2.3) *Glare.*

The brightness contrast in the surgeon's field of view, that is the difference in brightness between the wound area and the background against which it is seen, is perhaps more important than the illumination. This background is usually white, red, or green, according to what colour cover is used. It is preferable to use coloured covers rather than white because the brightness contrast will then be reduced. Gowns, caps, and masks could also conveniently be pale green. or some colour other than white

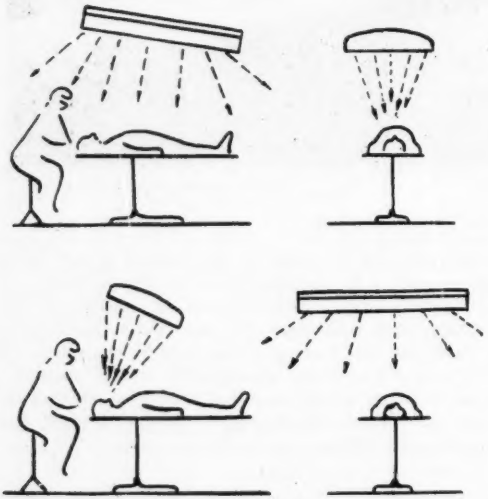

Fig. 6. Use of operating theatre fitting for Hare-lip operation.

(Top) incorrect. (Bottom) correct

Many hospitals have the lower part of the theatre tiled green, and this would seem to be better than having white tiles from floor to ceiling.

(3.2.4) *Adaptability.*

Although it is often insisted that an operating theatre fitting should be adjustable in height and direction, the authors have found adverse criticism to be levelled against a unit because its lighting possibilities were neither appreciated nor exploited. It is suggested, therefore, that some member of the theatre team should acquire a knowledge of the lighting fitting, because for any operation there is only one position of the fitting, in relation to the patient, which gives the maximum comfort to the surgeon. For example, in one theatre equipped with a fluorescent operating theatre fitting, a surgeon was repairing a hare-lip by plastic surgery. The particular fitting was equipped with five 80-watt lamps, each in an elliptical reflector which controlled the light in one plane only. The five reflectors were so arranged that a band of

maximum intensity covered the length of the table. As he sat at the head of the patient the surgeon justifiably complained that the light was glaring. The reason was easy to find. The fitting was being used in the normal way, but the surgeon was in an unusual position, which placed him in the main beam of the fitting. It would have been more satisfactory if the fitting or the table had been turned through 90 deg. and the fitting tilted so that the band of high intensity was across the patient's mouth and not on the surgeon, who would then not have been subjected to the discomforting glare. (Fig. 6.)

(3.2.5) *Colour.*

The choice of colour of the light in the theatre will lie between that of tungsten filament lamps, which has been familiar for many years, and that from the various forms of near-daylight lamps which may be filament lamps corrected with suitable filters or the much more efficient fluorescent lamps. Of these it would seem that, other things being equal, lighting of a near-daylight quality must be most acceptable.

Tungsten lamps give a distorted colour rendering, although the distortions are so familiar to everyone as to pass unnoticed. Colour distortions due to fluorescent lamps, while much less in magnitude, occur in a different part of the spectrum and are therefore probably more noticeable. The standard colour-matching fluorescent lamp gives the surgeon sufficiently accurate rendering of the colours which occur in his work, and it must be remembered that research work likely to result in further improvement is always going on. If a surgeon or an anaesthetist should consider that the colour rendering of any fluorescent lamp by itself is unsuited to his requirements, it should be possible to meet his needs by using it in combination with other lamps of the present range.

(3.2.6) *Comfort.*

The lighting engineer will want to ensure that his fittings are as comfortable as possible to work under, because there may be occasions when the surgeon has to take several hours performing one operation. This "working comfort" depends partly on control of unwanted heat from the fitting and partly on the elimination of glare.

The control of unwanted heat radiation is comparatively difficult in the fittings which use filament lamps in a very accurate optical system, because the heat is reflected in the same way as the light. A heat-absorbing medium may be used, but this will result in a reduction of illumination and some change of colour. In temperate climates it is usual for surgeons to use the fitting without this device.

The fluorescent lamp fitting does not concentrate the heat in the same way because it operates with a much larger light source and may not be expected to cause discomfort to the surgeon due to heat. As a rough indication of this, a measurement taken in still air has shown that a grey painted plate having a heat absorption equal to that of the human skin rose in temperature by only 1 deg. F. after

Table 4.

Energy Emitted by Electric Lamps

Type of lamp	Percentage energy emitted		
	Light	Infra-red radiation	Convected and Conducted
Tungsten filament	8	80	12
Hot Cathode fluorescent	20	40	40

45 minutes under such a fitting. Table 4 shows the comparative quantities of radiated heat from tungsten and fluorescent lamps.

The symptoms arising from bad ventilation are very similar to those which obtain under a bad lighting system. If, after a long and arduous operation, a surgeon suggests that the fitting was uncomfortable to work under, his report should be examined very carefully, for it may be possible to show that the discomfort which he experienced was due to the air in the theatre having become partially exhausted. In addition to this the ambient temperature in the theatre is often between 80 deg. to 100 deg. F.

(3.2.7) *General Lighting.*

It is difficult to decide on the minimum amount of general lighting, as many surgeons, desiring to have their attention focused on the operation area, find that to much general lighting is distracting. Nevertheless, other members of the team who are watching the progress of the operation will become adapted to the high brightness of the operation area, and may experience difficulty when they turn away to perform some task, if there is insufficient general lighting. A level of 15-20 lm./sq. ft. should therefore be regarded as a minimum for members of the theatre staff other than the surgeon to carry out their duties efficiently.

(3.2.8) *Supply.*

Reference must be made to the need for some system of emergency supply to ensure continuity of illumination in the event of a failure of the main power supply. This emergency stand-by may be drawn from a separate main at normal voltage, or from a storage battery. In either case the supply is brought into operation by a relay system when the main supply fails. The instant start circuit for fluorescent lamps can be used advantageously in operating theatre fittings to obviate the short period of intermittent illumination associated with the starting of fluorescent lamps by means of thermal or glow starters. Under present-day conditions of uncertain supply voltages, it might be desirable to use in conjunction with fluorescent lighting equipment some form of auto-transformer to maintain the voltage constant.

An ingenious system of indicator lamps operating through relays is in use at the Royal Infirmary, Edinburgh, by means of which a fault on any of the services is instantly shown on a central panel.

(3.3) Systems of Lighting

Having considered the way in which the foregoing requirements can be met, various systems of lighting for operating theatres will now be discussed.

(3.3.1) *Circular Single-lamp Fittings.*

The circular, single-lamp fitting is probably the most familar fitting in use to-day. It is a very efficient optical instrument, for it provides a small but adequate area of high intensity, although it uses an ordinary tungsten filament lamp of only 150 or 200 watts. Because the light cone is narrow, it has good penetration for deep cavity work. Emergency lighting is provided in the fitting, and its simple exterior design makes it easy to keep clean.

The illuminating engineer might criticise it because it may have to be moved during an operation. Elaborate systems with counter-weights, travelling gear, and quadrant arms have been devised for this purpose. The other criticism is that radiant heat from incandescent lamps is considerable, and since the optical system focuses the heat as well as the light it may prove troublesome to the surgeon.

(3.3.2) *Headlights.*

These small units carried on a band or cap and worn by the surgeon give a narrow beam of light from a reflector into cavities which cannot be lighted in any

other way. They cannot take the place of a permanent theatre fitting and are usually used by themselves for ear, nose and throat work. They should be regarded as a necessary evil, for they can be neither comfortable nor pleasant to work with.

(3.3.3) *Multi-lamp Ceilings.*

Systems have been constructed using a number of light sources disposed in a circle or circles around the table and concentrating their light towards the operating area. The system is flexible in that each lamp can be separately controlled to produce directional lighting as required. This adaptability, however, is only achieved at the expense of the illumination. A very heavy overall electrical loading is involved, and the resulting illumination has often been found inadequate.

(3.3.4) *Elliptical Dome.*

An interesting system has been installed in an operating theatre at the Royal Infirmary, Edinburgh. The ceiling of the theatre is built in the form of an elliptical dome with the operation area at one focus and the light source, in a small projector room, at the other. The light source is a 1,000-watt projector floodlight, controllable in direction from the theatre through a lever system. The reflecting dome is covered with stainless steel panels, which have been given a hammered finish to reduce striations. (Fig. 7.)

Fig. 7. Elliptical Dome Theatre—without natural light.

By tracing the light from the filament, it will be seen that some is concentrated by the reflector of the floodlight into a beam, and after reflection from the dome reaches the patient from a preferred direction. The remainder goes to all parts of the dome and is also reflected to the patient. Thus local and general lighting are produced automatically at the operation area. The maximum intensity has been found to be 200 lm./ft.^{2}

An advantage of this system is the complete absence in the theatre of any fitting. With a 1,000-watt lamp, it has been found necessary to use a water filter to absorb the heat concentrated in the beam. Daylight enters the theatre by windows in one

side wall, but during an operation the windows are covered and only artificial illumination used.

(3.3.5) *Multi-lamp Fluorescent Reflector Fittings.*

These fittings utilise a number of fluorescent lamps in reflectors so arranged that the beam from each lamp overlaps the others to give a high intensity over the whole table. The advantage of the fitting is that there is usually no need to move it during an operation, because the whole table is illuminated with light of a "shadowless" quality. The fitting has provision for emergency lighting, should the main supply fail.

(3.3.6) *Summary of Types of Fitting.*

The details of the foregoing fittings are shown in Table 5.

Table 5.

Operating Theatre Lighting Systems

	Circular Tungsten fitting	Headlight	Multisource system	Elliptical dome	Fluorescent reflector fitting
Surface illumination	Excellent	Poor*	Fairly good	Good	Very good
Cavity illumination	Good	Excellent	Poor	Good	Fairly good
Shadowlessness	Excellent	Poor	Fairly good	Excellent	Excellent
Working comfort	Good	Fairly good	Excellent	Excellent	Good
Adaptability	Very good	Excellent	Fairly good	Excellent	Good
Glare to surgeons	Very good	Excellent	Good	Very good	Very good
Glare to others	Very good	Poor	Good	Very good	Good
Colour rendering	Fairly good	Good	Fairly good	Fairly good	Excellent
Unobtrusiveness	Good	Fairly good	Excellent	Excellent	Good
Ease of cleaning	Good	Fairly good	Fair	Excellent	Fair

* Not intended for surface illumination.

(4) Dental Lighting

(4.1) Requirements

The requirements for dental lighting are firstly to give the surgeon adequate lighting for his work, and, secondly, to do this with the minimum of inconvenience to the patient. For psychological reasons, simplicity is desirable and the possibility of providing lighting similar to that given by large windows by daytime must be considered.

An illumination level within the mouth of the patient of 100 lm./ft.^{2} would not be excessive, and will allow the dentist to redirect the light in the mouth by means of small mirrors.

Shadowlessness must be considered as the hard shadows produced by a small concentrating spotlight would not be satisfactory.

Colour of lighting is important to the dentist and if it is possible to use natural or artificial daylight lamps, this would be an advantage.

For convenience, the dentist would prefer a lighting installation that does not require to be critically adjusted whenever the patient is moved.

An illuminated X-ray viewer is required which the dentist can use while at work. There is a danger that such a viewer can cause glare when the film is not large enough to cover the illuminated area.

(4.2) Recommendations

If it is accepted that a very small source of high brightness will produce illumination with shadows that are too hard, then the choice for the surgeon's light must be between a very large source whose brightness is low enough for the patient to experience no discomfort, or a somewhat smaller source of higher brightness whose beam is so accurately controlled that a cut-off can be provided between the patient's mouth and his eyes. If the fitting is 4 ft. from the patient's face, the angle between maximum candle-power and cut-off should not exceed 3 deg.

(4.2.1) *Large Sources*

Under the heading of large sources of low brightness, the following arrangements have been installed.

A single two-light 80-watt fluorescent reflector fitting, permanently placed slightly in front of and above the patient. This provides good shadowless lighting, but the intensity of about 40 lm./ft.^{2} is rather low. There is some glare from the bare tubes, but a number of dentists have found this simple arrangement far better for their work than previous multi-lamp brackets with tungsten lamps.

Three two-light 80-watt fluorescent fittings can be used to outline the top and sides of the window. This gives some glare as before, which be can reduced if there is an illuminated light-coloured blind over the window. Consumption is rather high for the illumination produced.

A four-lamp fitting using 40-watt fluorescent lamps in concentrating reflectors has been designed as a smaller version of the 5 ft. multi-lamp operating theatre fitting described elsewhere in this paper. A counter-balanced suspension is incorporated in the fitting itself so that the unit will remain in any desired position. There is some glare to the patients, but the brightness of 4 ft. 40-watt lamps is not as great as 5 ft. 80-watt lamps and the illumination is good (over 100 lm./ft.^{2}), and relatively shadowless.

(4.2.2) *Controlled Reflectors*

Circular fittings, similar to operating theatre fittings but of smaller size and mounted on a portable stand, are favoured by some dentists. The control is not usually sufficient to ensure that there is no glare to the patient, but the mouth illumination is good. An alternative is a fitting about 2 ft. square, equipped with one or more 2 ft. 20-watt fluorescent lamps. By using aluminium for the body of the fitting the weight is kept to a minimum and so the fitting can be carried on an adjustable bracket attached to the dental unit. It should be possible to design a unit of this type to satisfy the requirements set out above, but the adjustment would be rather critical.

(5) Pathological Department

The provision of a light of daylight or near-daylight quality is considered to be of prime importance for the study of morbid conditions. A fairly high intensity of light is required and twin-lamp fittings with daylight or natural fluorescent lamps have been found to be satisfactory. It is likely that the colour-matching lamp, newly added to the range of fluorescent lamps, will prove to be better than either of these. The

lighting should be free from hard shadows, but it is recognised that for certain examinations where the detection of shallow irregularities in tissues is involved, the fluorescent lamp may be too shadowless and the addition of directional lighting may be necessary. It is suggested that a satisfactory position for a lighting fitting is about 4 ft. above the bench level over the head of the pathologist.

(6) Museums

The lighting problem in a hospital museum is twofold. Firstly, it must be possible to select a required exhibit from the shelves, and, secondly, to examine it closely. The exhibits are often pickled in glass jars and irritating reflections must be controlled. This can be done by using screened fittings mounted high over the gangways between the shelves in which circumstance the reflections that result will be directed towards the floor.

The high intensity required for the examination of specimens may be obtained either by placing the tables so that they receive direct illumination from the fittings which are lighting the shelves, or by providing local lights on the tables.

(7) Conclusion

It is well known that, at least so far as their work is concerned, surgeons are a cautious race. The task of the lighting engineer who has produced what he considers to be the perfect lighting instrument for the operating theatre is therefore not easy. He may extoll its merits at some length and prove conclusively that the new idea is better than the old, but the surgeon's reply is: "If you want me to remove your appendix, would you rather I use the fitting I like or the one you are trying to sell me?" Surely, the surgeon must have the last word?

DISCUSSION

MR. HAROLD BRIGHT, commenting on the importance of avoiding glare in wards, said there should be a great deal more co-operation between the lighting engineer and those responsible for the decoration of the wards. It had been suggested that there should be a high measure of indirect lighting in wards; it was, however, customary to paint both the walls and ceilings of wards with a high-gloss paint, the effect of which from the point of view of glare could be very disconcerting. He urged that paint used on wards should have a semi-matt finish.

The question of reduced intensity of illumination in wards, and particularly in corridors at night, he said, was a matter which called for some form of voltage control at the lamp terminals. It was true that there were fittings which contained a second bulb, but in some cases this was a nuisance; it also resulted in an expensive type of fitting. In order to obtain reduced intensity of the illumination in wards, and particularly in corridors, without affecting the light distribution, it was desirable to alter the voltage at the lamp terminals. For the control of individual lamps on alternating current circuits, a convenient way was to provide a condenser which could be connected in series. The advantage was that if a lamp of increased wattage were accidentally fitted, no harm was done to the condenser, whereas resistance dimmers would overheat and be damaged.

Operating theatre lighting, he said, had been dealt with so exhaustively by the authors that there was not much he could usefully add. It seemed to him that a system of lighting which involved a group of lamps arranged in a circle around the operating table had the advantage that there was no chance of dust falling on to the operating table. He had always felt it might be worth experimenting with a ring of

fittings coupled mechanically to a control lever so that the light could be made to approach the table from a preferred direction. That result had been achieved much more elegantly in the ingenious arrangement of the elliptical ceiling described in the paper, but he wondered if cleaning the reflectors would not present a difficulty.

Although not strictly a problem of lighting, he felt that emphasis should be placed on the risk of explosions in operating theatres. It was essential at times to use portable lights, and headlights had also been suggested in the paper, but the inflammability of ether was so great that these fittings should be carefully designed and used with great discretion.

MR. FRANK LAW (President, Faculty of Ophthalmologists), after expressing his appreciation of the invitation to be present, said he offered no excuse for attending because he was very conscious of the necessity for a link-up between doctors and opticians and illuminating engineers, which was not as strong as it should be. There was a great deal of ignorance about the illumination values for various kinds of activity, and the more the doctors and opticians could learn from the illuminating engineer the better.

Agreeing that in wards there must be general and also local lighting, he said the mobility of the latter was important, and he wondered whether it would be a constructive idea to suggest the use of adjustable fittings at the head of the bed. He admitted these were ugly fittings, but he thought they would provide the examining surgeon or physician with a more useful light and from the point of view of the patient be quite satisfactory.

Commenting on the discomfort experienced by patients lying in bed and having to look at windows on the opposite side of the ward with bright daylight coming through, he said the suggested remedy of putting the beds lengthwise in the ward instead of as at present would entail nursing difficulties, and it was also extravagant in space. It was interesting, he said, that it was far less uncomfortable to be near a bright window than a little distance away from it.

Referring to the circular single lamp fitting with reflector, he said he did not like it, particularly for intraocular work, and much preferred the portable "hammer-lamp." However, it was essential for the person holding it to know what was going on, and in the hands of an inexperienced nurse difficulties might arise, such as the shadow of the instrument or hand being thrown on to the eye of the patient. He did not think the authors had referred to this type of lighting except once, and then it seemed they rather condemned it, but he still regarded it as the ideal form of lighting for ophthalmic work. Headlamps, he thought, were horrible. For eye work they were dangerous because the site of operation was left quite unilluminated when the surgeon turned away for an instrument.

As regards the elliptical dome system, he was one of a party who had inspected this when it was thought likely to be applicable to eye work, but he had taken the trouble to lie on the operating table and had found that the glare was intolerable. Most patients undergoing eye operations were conscious, and it would have been misery for them.

In connection with museums, he said he had been responsible for one at Moorfields, but it had since been dismantled and transferred to the Institute of Ophthalmology. It was an interesting problem, and the lighting must be of a reasonable standard so far as the room itself was concerned. Specimen cases were a different problem, and he had adopted the 60-watt daylight lamp in an adjustable fitting so arranged that there was overlapping illumination from the various fittings. When a student wished to examine a specimen, the fitting could be pulled close down to the specimen for this purpose. That was a useful and effective method of museum illumination, although ugly in appearance.

DR. D. V. BATEMAN (Department of Anaesthesia, London Hospital) said that whilst surgeons were primarily concerned with the intensity of illumination at the point of operation, his problem as an anaesthetist was the continuous assessment of the patient's condition, and this involved recognition of colour changes in the blood pigments. No anaesthetist pretended that tungsten light gave the same colour-rendering as natural daylight, but he had, over the years, become accustomed to it and was able to make the necessary allowances for it in assessing the patient's colour. The recent introduction of fluorescent lighting into operating theatres had complicated the problem still further. In the attempt to get an accurate rendering of the colour of human blood, recourse had been had to batteries of tubes of two or more shades in a reflector. The danger here was that one of the tubes might break down unknown to the anaesthetist in his temporary absence, and he would return to find a quite different colour-rendering. Again, he might get accustomed to one variety of tube in one hospital and be confused on visiting another hospital where a different tube or combination of tubes was in use. Even with the most recently introduced "colour-matching" tube he and his colleagues at London Hospital were still not happy about the appreciation of fine degrees of colour change in the blood. It might well be that with two or three years' experience they would acquire the same confidence in it as they now had in tungsten light, but he was concerned that hospitals should be encouraged to standardise the particular type of tube in use to minimise the dangers of different renderings. With reference to head-lamps and other low-voltage lighting appliances used close to the patient, anaesthetists were already acutely aware of the explosion hazard, and had perforce to use non-explosive agents for anaesthesia when they were in use.

MR. R. LANG (Ophthalmic Surgeon, Royal Surrey County Hospital) said that he was interested in the use of fluorescent lighting in hospital wards, and had been privileged to conduct some experiments with the authors.

Whilst he knew nothing about the technical side of illuminating engineering, his interest in ward-lighting had been stimulated in various ways. First of all, by an article by Ferree and Rand in the "British Journal of Ophthalmology" in 1942, in which they described a system of ward lighting using ordinary filament lamps in various fittings. Another matter that had stimulated his interest was the complaint of glare which had arisen in a sanatorium in the wards of which the beds were so placed that the patients had to face the glare from windows on the opposite side of the ward. Here he rather crossed swords with Mr. Law as to the possibility in the future of arranging beds parallel with the walls of the hospital. He had recently seen two plans, one drawn up by a leading hospital architect, in connection with his own hospital, in which the architect, without any consultation with him, had arranged the beds parallel to the wall. That plan was actually drawn up just before the war. There was also another one, also drawn up by a famous hospital architect, which also had the beds parallel to the wall. He hoped that that arrangement would be the usual thing in the future. If that came about, then the lighting would have to be adjusted, because fluorescent lighting as now placed in the wards would not do.

He had carried out some experiments with louvres. His attention had been drawn to an article in the "Hospital Officer" which said that it was impossible to screen fluorescent lighting and make it useful in hospital wards, but after seeing the pictures shown by the authors they would all probably think it was worth considering. One of the difficulties in ward lighting was to arrange both for evening lighting and night lighting and to combine both in the same fitting. There were also personal idiosyncracies on the part of the patients. There were some who were perfectly happy with the light falling in the wrong direction, whilst others would immediately be uncomfortable if the lighting was not just right. In his own hospital there had been difficulty in connection with the small blue light in the old type of

fitting, and some patients had said they could not sleep because of this blue light; but he had been told that there had been no complaints in the ward now fitted with the fluorescent lighting fittings described in this paper. Incidentally, the old blue light was preferred by the night staff in his hospital.

In the case of individual fittings, care must be taken that patients on the opposite side of the ward do not see too much reflected light from the inside of the shade, the bottom of which must be parallel with the floor.

As regards reflecting fittings, the aim must be to light the ceiling and as much as possible of the walls. This meant that the top of the tube could be as high as the outside edges of the fittings, but no higher, otherwise there would be reflections from the windows in the ward.

Measurements made at the head of a bed showed the illumination to be of the order of 1-ft. candle, but it was not a good thing for a patient to read with such an illumination. He agreed that highly glazed ceilings and walls should be avoided. The floors should be light in colour, as well as the ceilings and walls.

He had grave doubts about the use of fluorescent lighting for operating theatres unless shorter tubes could be used, with a consequent smaller area of illumination. He did not think many surgeons could stand up to the larger tubes shown in the authors' illustrations.

There was a point in connection with fluorescent lighting and X-ray work. Some surgeons were very fond of having the patient X-rayed and taking the wet film straight back to the viewing screen. With the ordinary lamp, if it were on for long periods, considerable heat was given off and the film stuck to the glass and melted. With a change to fluorescent lighting that difficulty was avoided.

DR. W. J. WELLWOOD FERGUSON (Lecturer in Ophthalmology, Sheffield University), said he also preferred the portable hammer lamp and had a horror of the headlamp. On the question of the position of beds in wards, he said that many of our hospitals were nearly 100 years old and even older, and all efforts to light them efficiently were conditioned by the appalling situation of the windows and the archaic ventilation which made efficient lighting difficult. He felt that the solution was along the lines of replanning the wards altogether and this might allow of the beds being placed parallel with the windows.

It was suggested in the paper that there might be a red light in the room where the nurses could do their administrative work at night so that they would not lose their degree of adaptation when going into the wards at night, but he rather saw difficulties in that connection.

In connection with the lighting of operating theatres in general, one point to be borne in mind was that there must be a minimum of reflected light, and here again the question of polished or highly glazed walls was of considerable importance, especially in connection with eye operations. When discussing the question of theatre lighting with the surgeon at Sheffield he was told it had been necessary to diminish the general illumination of the theatre so that when the surgeon was looking into dark cavities his adaptation was not conditioned by the high degree of lighting of the theatre.

MR. C. R. BICKNELL said there were one or two things in the proof of the paper which might with advantage be attended to before it appears in the Transactions. In Table 3 was given a list of different sources of illumination at the working area in operating theatres, and it would be an advantage to have added to this the wattage consumptions for the different types of light source. It would then be possible to make an assessment of the actual efficiency of these different sources.

Criticism had been invited by Mr. Peirce of Table 5, which dealt with operating theatre lighting systems, and this table had got him "fogged." Under "Colour Rendering" the circular fitting and the elliptical dome were stated to be "fairly good," whereas

the much despised headlight was given as " Good." Since all three systems incorporated lamps emitting light of substantially the same quality would Mr. Peirce say how he arrived at these conclusions ?

Under the heading of Dental Lighting it was stated, " Colour of lighting is important to the dentist, and if it is possible to use *natural or artificial daylight lamps* this would be an advantage." What did that mean? He could not understand it.

Lower down, reference was made to the use of multi-lamp brackets with tungsten lamps, a common form of which was a four-lamp daylight-lamp unit with prismatic bowls. Could the authors say what was the surface brightness of such fittings?

With regard to the second slide that had been shown, Mr. Reed spoke about the open type fluorescent fitting with a 45 degree cut-off allowing light to reach the walls, whilst Mr. Lang stated that it was essential that the tops of the lamps be no higher than the sides of the fitting. How, since the sides of the fitting were completely opaque, did the light get on to the walls?

MR. C. J. MISSELBROOK, referring to the question of night lighting in wards, said that one possible solution was to be found in a fitting which had a reversible metal reflector. Normally this would give direct lighting at the bed head, but at night-time the metal reflector could be reversed and give an indirect light with a low intensity of illumination.

The authors had made the statement that the nearer the lighting in the operating theatre was to natural lighting the better the surgeon would be pleased. To this should be added the words " after experience." Mention had already been made by Dr. Bateman of the dangers which might arise from the lack of familiarity of colour tones by the anaesthetist and experience of any system of lighting was necessary.

MR. W. F. GRIFFITHS said that, whilst the authors had mentioned the use of standard fluorescent fittings for dental work and also a special fitting using four 40-watt 48-in. lamps, they had omitted to refer to another type of surgery unit which had been developed and was in use both in this country and America. The type he had in mind was designed to replace the orthodox tungsten lights commonly used with adjustable dental arms.

One in question used two 2-ft. 40-watt tubes. These were placed horizontally in parabolic reflectors so arranged that the beams converged on the patient's mouth, the light from the lamps and flashed area of the reflectors being diffused by a lightly etched large area perspex screen. The advantage of this equipment was that it permitted the use of the existing adjustable arm; consumption was lower, yet an intensity of the order of 40 foot-candles was produced at the mouth with cool operating conditions. These fittings had achieved considerable success and the colour of the natural fluorescent lamps used was claimed to be beneficial, especially as an aid to the early detection of cyanosis.

MR. F. BAKER said there was one important point he would like the authors to clear up for him. The multi-tube unit had been mentioned as being highly efficient in an operating theatre, but bearing in mind the risk of explosion due to ether gas and the proximity of the fitting to the table, what precautions have been taken to safeguard against explosion?

In reply to the discussion the AUTHORS said that, in connection with Mr. Bright's contribution, they agreed that it is very desirable to use matt paint and so avoid the unpleasant effect which occurs with highly glossy ceilings and walls. The control of voltage at lamp terminals is an interesting method of producing low intensity lighting and should certainly receive serious consideration in any hospital. Cleaning of the " eliptical dome " system of operating-theatre lighting is comparatively easy since the surface is of stainless steel and there are few ledges for the collection of dust.

In reply to Mr. Law, the discomfort to patients who are a little way back from the

window is entirely due to the excessive contrast between the brightness outside and the comparatively low brightness of the interior wall; when the patient is nearer to the window his eye becomes more nearly adjusted to the exterior brightness and so the effect of glare is reduced.

With regard to the "hammer lamp," they did not intend to condemn this type of light, or indeed any type of local lighting, except to say that where it is possible to carry out the lighting without the use of these items it was preferable to do so.

With regard to the eliptical dome theatre at Edinburgh, this was intended for neuro-surgery so that in this instance the patient would be unconscious. It was interesting to note that Mr. Law considered that from a patient's point of view this installation was more glaring than others.

In reply to Dr. Bateman, the authors gave full support to his suggestion that there should be standardisation of colour of tubes both for the anaesthetic room and the operating theatre. They felt, however, that the nearer the colour value could be to that given by north sky daylight, the more likely are the standards to remain the same over a period of years.

In reply to Mr. Lang's comments with regard to the use of 5-ft. lamps in operating theatre fittings, they thought that the effect of the large illumination area to which he referred can and should be reduced by the use of dark-coloured sheets by which the patient is covered.

In reply to Mr. Bicknell's point regarding wattage of the source of illumination in the operating theatre fitting, these wattages are mentioned in the body of the paper and it was not thought that they could be included in the table as a reason for or against using a particular type of light in such an important situation. With regard to Table 5, the point was that the headlight incorporates a lamp running at high efficiency, and, therefore, the light might be expected to be of slightly better colour quality than that from fillings using general service lamps. (It has been considered after Mr. Bicknell's remarks that it would be better to give these items the same mark as "Good.") In connection with dental lighting, the point to which he refers was a typographical error in the galley proof and has been corrected.

With regard to the surface brightness of the prismatic bowls used with multi-lamp brackets, the makers of these bowls calculated the brightness as an average over a small area. It is true, however, that these bowls can sometimes be a source of glare to the patient.

With regard to Mr. Ferguson's remarks in connection with the theatre lighting at Sheffield, the authors were of the opinion that the surgeon's adaptation would be conditioned more by the brightness near the cavity than by the brightness of the general illumination of the theatre. The high brightness immediately surrounding the cavity can only be reduced by the use of cloths of dark colour.

The authors thanked Mr. Griffiths for bringing to their notice equipment developed for dental lighting which had not been mentioned in the paper.

Mr. F. Baker raised the question of danger from explosion in using a multi-tube operating theatre unit. This question has been taken up fully with Mr. Swan, Chief Electrical Inspector of Factories, who expresses himself satisfied as to the safety of the unit.

In reply to Mr. Misselbrook, the authors were very interested in the reversible metal reflector fitting and no doubt this would meet with approval in a number of instances. It would seem that some means of reducing the brightness of the lamp for night lighting would be desirable and possibly the inclusion of a condenser as suggested by Mr. Bright would satisfy this.

Additions to List of Members

The following applicants have been duly elected by the Council to membership in the Society, and their names have been added to the list of members.

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City of Birmingham Education Department,.....*Representative*: C. F. Partridge.
Council House, Margaret Street, BIRMINGHAM.

Harrisons Lister Engineering, Ltd.....*Representative*: H. J. Hawkins.
96, Ampang Road, Kuala Lumpur, MALAYA.

CORPORATE MEMBERS:—

Ball, P. A. .....19, Malvern Road, Acocks Green, BIRMINGHAM.
Bayfield, T. .....62, Danum Road, Fulford, YORK.
Bland, R. .....7, Hope Park Road, Prestwich, LANCS.
James, F. E. .....80, Gladstone Street, Basford, STOKE-ON-TRENT.
Leavey, L. A. .....20, Cobden Terrace, Wilfrid Road, Street, SOMERSET.
LeMarechal, W. T. .....19/23, West Campbell Street, GLASGOW.
McBride, T. J. .....328, Griffith Avenue, Dublin, IRELAND.
Tagg, C. S. .....23, Warser Gate, NOTTINGHAM.

STUDENT MEMBERS:—

Foxell, C. A. .....19, Beechwood Gardens, South Harrow, MIDDX.
Phillips, C. McN.....16, Upton Road, Watford, HERTS.

Register of Lighting Engineers

The Council have accepted the following applications for inclusion on the Register of Lighting Engineers:—

D. C. Battie.
W. H. Dodgson.
N. I. B. Harrison.
R. A. Lovell.
J. A. Prowse.
D. T. Russell.
A. G. Smith.

Corporate members of the Society are reminded that from February 1, 1950, all applicants for inclusion on the Register will be required to hold the Intermediate Certificate in Illuminating Engineering of the City and Guilds of London Institute. Those wishing to make application under the present Regulation 6, whereby the educational requirements may be waived in respect of those with approved practical experience, must do so before February 1 next.

A further amendment to the Regulations governing the inclusion of the names of Corporate Members in the Register will also come into force on February 1. At present, applicants other than those applying under Regulation 6, are required to have been engaged in the practice of illuminating engineering for a period of not less than three years. This period is now to be increased to not less than *five years;* with the exception that, in the case of applicants who have already obtained a recognised standard in an allied field, the period may be reduced to three years.

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Session 1949—1950

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Printed by ARGUS PRESS LTD., Temple-avenue and Tudor-street, London, E.C.4., England.